Technical debt, refactoring, and maintenance (1/2)

Martin Kellogg

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Today's agenda:

- Finish design pattern slides
- Reading Quiz
- Technical debt: the costs of bad design
- How to pay off technical debt: refactoring

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Software Architecture (Part 2 of ~~3~~ 2)

~~Today's~~ Tuesday's agenda:

- Reading Quiz
- Strategies for good design
- Design patterns
  - Structural patterns
  - **Creational patterns**
  - Behavioural patterns

Creational patterns: factories

- Suppose we need to create and use polymorphic objects **without exposing their types** to the client
  - Recall: design for maintainability and extensibility. We don't want the client to depend on (and thus “lock in”) the actual subtypes.
- The typical solution is to write a function that creates objects of the type we want but returns that object so that it appears to be (“cast to”) a member of the base class
  - this is a specific variant of the named constructor pattern

Creational patterns: factories

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Payment * payment_factory(string name, string type) {
 if (type == “credit_card”)
   return new CreditCardPayment(name);
 else if (type == “bitcoin”)
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 … }

Payment * webapp_session_payment =
 payment_factory(customer_name, “credit_card”);
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Creational patterns: factories

- The *factory method pattern* (or
  design pattern that uses facto
  without having the return type

Note how the implementation details are hidden from the client, and they can only treat the result as a generic payment

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Creational patterns: factories

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```
class PaymentFactory {
public:
 static Payment* make_credit_payment(string name){
   return new CreditCardPayment(name);
 }
 static Payment* make_bc_payment(string name){
   return new BitcoinPayment(name);
 }};
Payment * webapp_session_payment =
PaymentFactory::make_credit_payment(customer_name);
```

Creational patterns: example

- Suppose we're implementing a computer game with a **polymorphic Enemy class hierarchy**, and we want to spawn **different versions** of enemies based on the difficulty level.

- e.g., normal difficulty = regular Goomba 

- hard difficulty = spiked Goomba 

Creational patterns: example: anti-patterns

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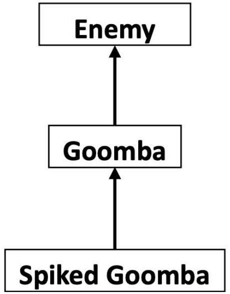

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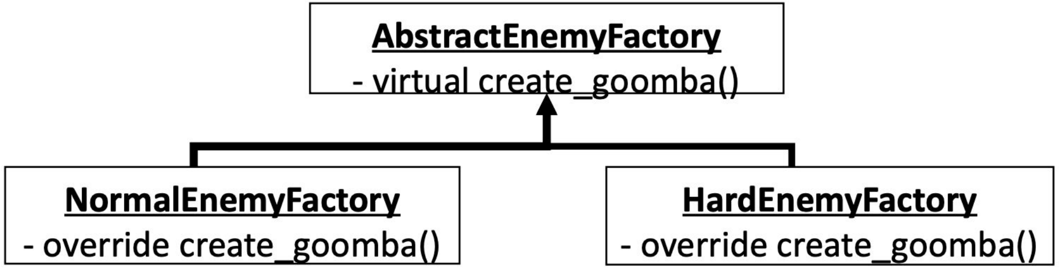

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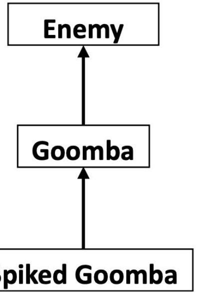

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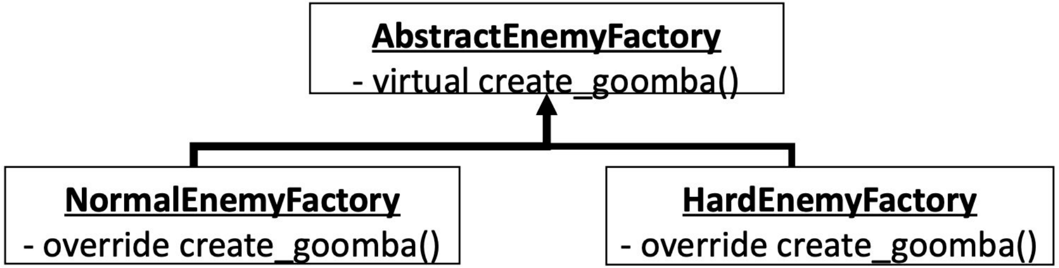


```
// Only have to do this once!
AbstractEnemyFactory* factory = nullptr;
if (difficulty == “normal”)
  factory = new NormalEnemyFactory();
else if (difficulty == “hard”)
  factory = new HardEnemyFactory();
Enemy* goomba = factory->create_goomba();
```

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- Suppose we have some application **state that needs to be globally accessible**. However, we need to control how that data is accessed and updated.
- The anti-pattern (**bad**) solution is to have an **unprotected global variable** (e.g., a public static field).
  - fails to control access or updates!
- A "less bad" solution is to put all of the state in one class and have a **global instance** of that class.

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    - This is not an argument for using global variables to avoid passing a few parameters.
  - Or if you need to access state stored outside your program (e.g., database, web API)
  - Then global variables **may** be acceptable

Singleton design pattern

- The ***singleton pattern*** restricts the instantiation of a class to **exactly one** logical instance. It ensures that a class has only one logical instance at runtime and provides a global point of access to it.

<u>Singleton</u>

public:

- static ***get_instance***() *// named ctor*

private:

- static ***instance*** *// the one instance*
- Singleton() *// ctor*

Singleton design pattern: example

```
class Singleton {
 // public way to get “the one logical instance”
 public static Singleton get_instance() {
   if (Singleton.instance == null) Singleton.instance = new Singleton();
   return Singleton.instance;
 }
 private static Singleton instance = null;
 private Singleton() { // only runs once
   billing_database = 0;
   System.out.println("Singleton DB created");
 }
 // Our global state
 private int billing_database;
 public int get_billing_count() { return billing_database; }
 public void increment_billing_count() { billing_database += 1; }
}
```

Singleton design pattern: example

lazy initializaton
of single object

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this constructor can't be called any other way

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all clients share this global state

Singleton design pattern: example

What is the output of this code?

<u>Singleton</u>

public:

- static ***get_instance***() *// named ctor*
- get_billing_count()
- increment_billing_count() *// adds 1*

private:

- static ***instance*** *// the one instance*
- Singleton() *// ctor, prints message*
- billing_database

```
class Main {
 public static void main(String[] args) {
   int bills = Singleton.get_instance().get_billing_count();
   System.out.println(bills);

   Singleton.get_instance().increment_billing_count();
   bills = Singleton.get_instance().get_billing_count();
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 }
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Output:

```
Singleton DB created
0
1
```

Singleton design pattern: get_instance()

- Could we avoid typing Single.get_instance() so many times by doing this at all of the points in our program that use the singleton?

```
Single s = Singleton.get_instance();
System.out.println(s.get_billing_count());
… // later
System.out.println(s.get_billing_count());
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```
Single s = Singleton.get_inst
System.out.println(s.get_bill
… // later
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```

- Is this a good idea or not?

This is a **bad idea**. There is **no guarantee** that get_instance() will return the same pointer (same object) every time it is called. (It may return different **concrete copies** of the **same logical item**.)

Singleton design pattern: another example

- Suppose we are implementing a computer version of the card game Euchre. In addition to a few abstract datatypes, we have a Game class that stores the state needed for a game of Euchre. When started, our application prototype plays one game of Euchre and then exits.

- Design question: **should we make Game a singleton**?

Singleton design pattern: another example

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  - Singleton is **not** a license to make everything global.

Behavioural Design Patterns

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  - Examples: strategy pattern, template method pattern, iterator pattern, observer pattern, etc.

Iterator Pattern

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  - e.g., Java's List interface doesn't care whether it's backed by an array or a linked list
- Similar patterns exist for other kinds of data structures
  - e.g., ***visitor pattern*** for tree-like structures

Strategy Design Pattern

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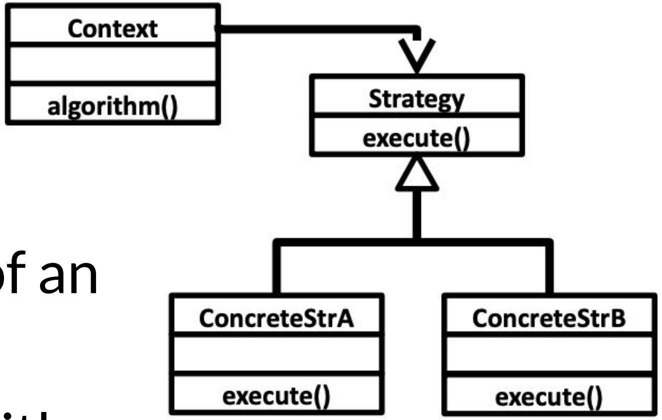

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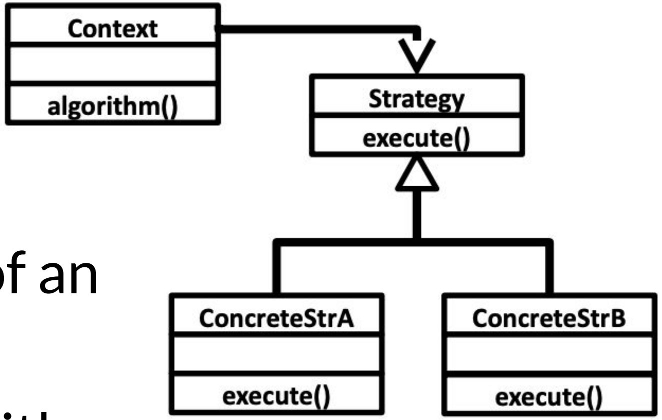

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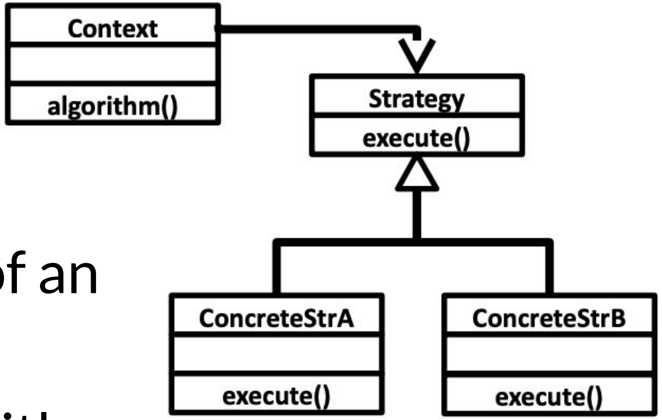

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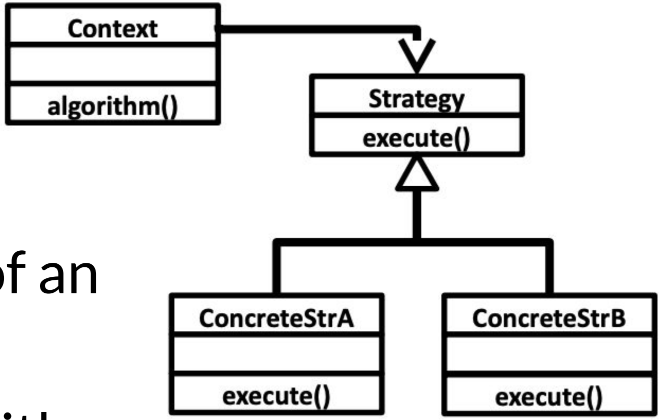

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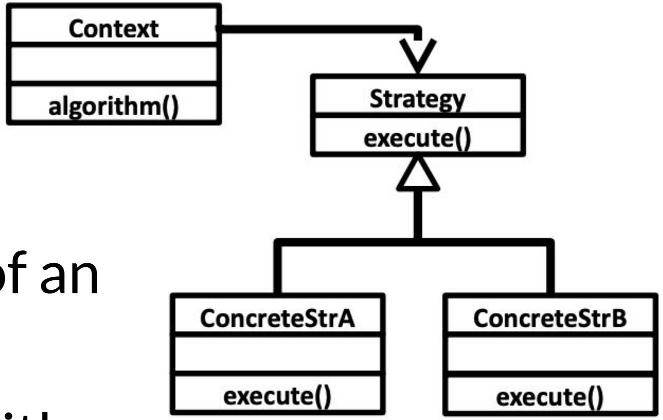

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    - Separates algorithm from client context
    - Introduces extra interfaces and classes: code can be harder to understand; adds overhead if the strategies are simple

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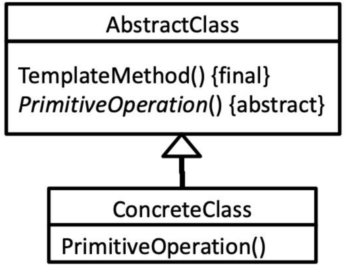

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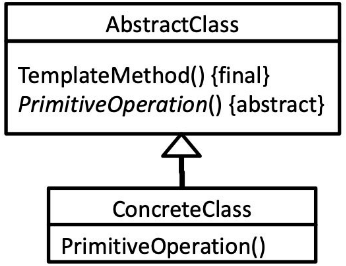

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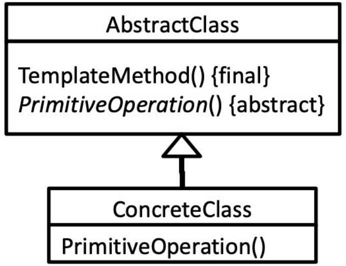

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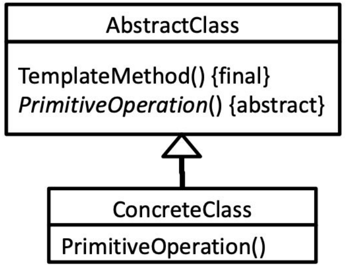

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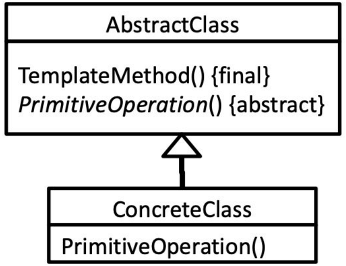

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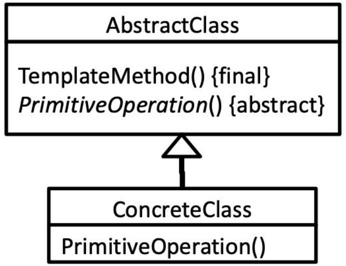

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  - Customization is restricted to the primitive operations
  - Inverted ("Hollywood-style") control for customization: "don't call us, we'll call you" (cf. comparison function in sorting)
  - Invariant parts of the algorithm are not changed by subclasses

Template vs. Strategy Design Pattern

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Template vs. Strategy Design Pattern

- Both support variation in a larger context
- **Template method** uses inheritance + an overridable method
- **Strategy** uses an interface and polymorphism (via composition)
  - Strategy objects are reusable across multiple classes
  - Multiple strategy objects are possible per class

Scenario: binge-watching

- Suppose we're implementing a video streaming website in which users can “binge-watch” (or “lock on”) to one channel. The user will then see that channel's videos in sequence. When the last such video is watched, the user should stop binge-watching that channel.

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class User {
 public void release_binge_watch(Channel c) {
   if (c == binge_channel) {
     binge_channel = null;
   }
 }
 private Channel binge_channel;
}
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```
class Channel {
 // Called when the last video is shown
 public void on_last_video_shown() {
   // Global accessor for the user
   get_user().release_binge_watch(this);
 }
}
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- What are some problems with this approach?

Scenario: binge-watching: anti-patterns

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Scenario: binge-watching: anti-patterns

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- Whenever requirements change and we want to do something else when a video finishes (e.g., update advertising) we **must update the Channel class** and couple it to the new feature

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What can we do instead?

Observer Pattern

- The ***observer pattern*** (also called "***publish-subscribe***") allows dependent objects to be notified automatically when the state of a subject changes. It defines a one-to-many dependency between objects so that when one object changes state, all of it dependents are notified.

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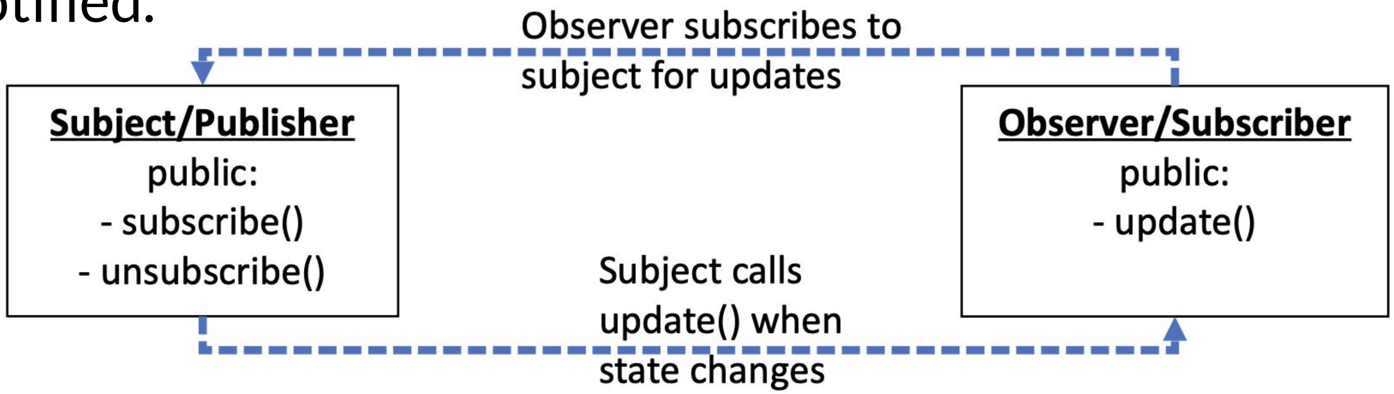

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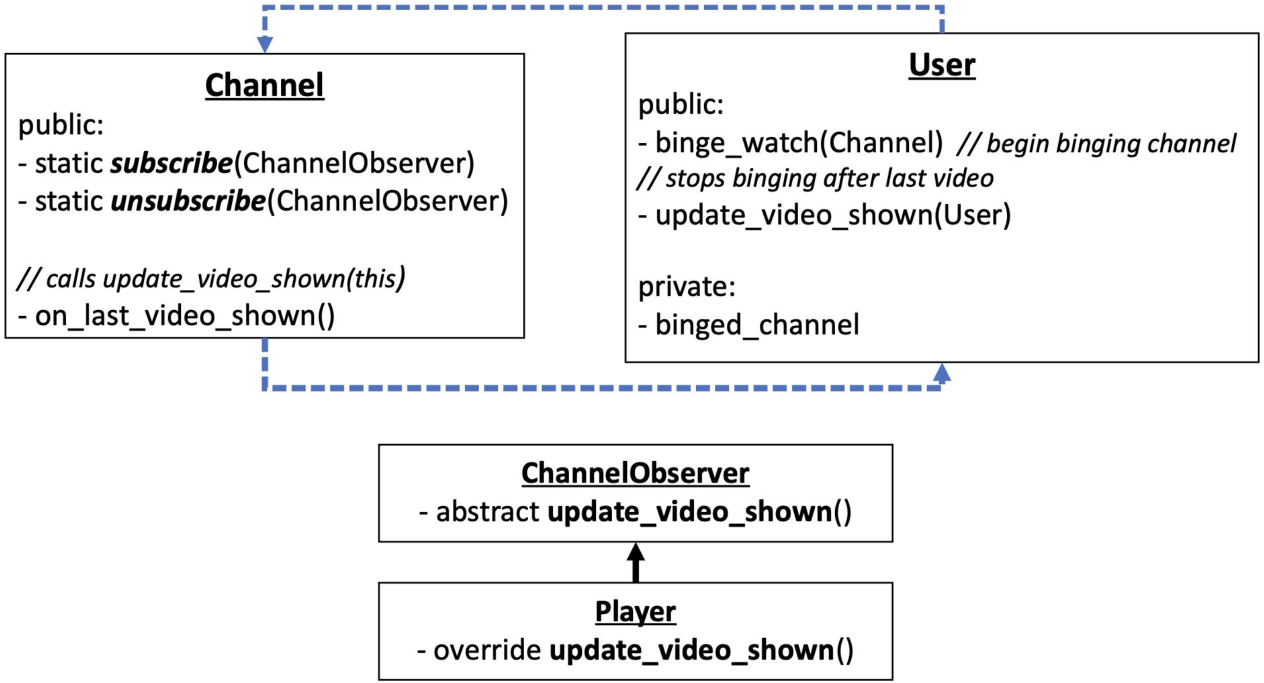

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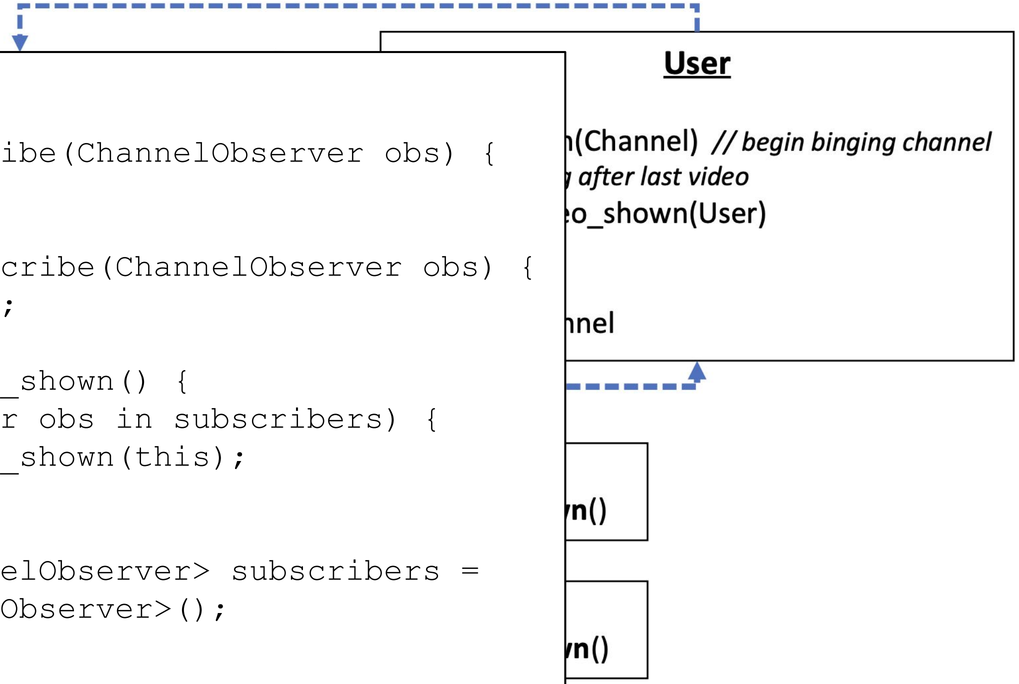


```
class Channel {
 public static void subscribe(ChannelObserver obs) {
   subscribers.Add(obs);
 }
 public static void unsubscribe(ChannelObserver obs) {
   subscribers.Remove(obs);
 }
 public void on_last_video_shown() {
   foreach (ChannelObserver obs in subscribers) {
     observer.update_video_shown(this);
   }
 }
 private static List<ChannelObserver> subscribers =
          new List<ChannelObserver>();
}
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interface ChannelObserver {
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```
class User: ChannelObserver {
 public void update_video_shown(Channel c) {
   if (c == binged_channel)
     binged_channel = null;
 }
 public void binge_watch(Channel c) {
   binged_channel = c;
 }
 private Channel binged_channel;
}
```

Observer Pattern: update functions

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- Having multiple "update_" functions, one for each type of state change, keeps messages **granular**
  - Observers that do not care about a particular type of update can ignore it (via an empty implementation of the update function)
- Generally it is better to pass the newly-updated data as a parameter to the update function (**push**) as opposed to making observers fetch it each time (**pull**)

Design patterns: takeaways

- Thinking about design before you start coding is usually worthwhile for large projects
  - Design around the most expensive parts of the software engineering process (usually maintainence!)
- Design patterns are re-usable solutions to common problems
- Be familiar with them enough to recognize when they're being used
  - and to know when to use them yourself
  - you can look up details of a pattern if you remember its name!
- Be mindful of and avoid common anti-patterns

Tech debt, refactoring, and maintenance (1/2)

Today's agenda:

- Finish design pattern slides
- **Reading Quiz**
- Technical debt: the costs of bad design
- How to pay off technical debt: refactoring

Reading quiz: tech debt

Q1: **TRUE** or **FALSE**: “technical debt” is money you owe to someone because of a technical decision that you made while implementing a system

Q2: **TRUE** or **FALSE**: all technical debt is the result of programmer laziness

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- analogy to **financial debts**:
    - you gain some immediate benefit
        - in a financial debt, you gain a large sum of money
        - in a technical debt, you gain implementation speed, etc.
    - you pay for it over time
        - in a financial debt, you pay interest
        - in a technical debt, your maintenance costs increase

Technical debt: benefits

- Why might you **intentionally** make a sub-optimal design decision?

Technical debt: benefits

- Why might you **intentionally** make a sub-optimal design decision?
    - Cost
        - either in dev time or because the code isn't done yet
    - Need to meet a deadline
    - Avoid premature optimization
    - Code reuse
    - Principle of least surprise
    - Organizational requirements/politics
    - etc.

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- **Implication**: a system with technical debt is **harder** to change and reuse

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- lose potential customers

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Whether to take on technical debt is often one of the **most consequential** choices you get to make as an engineer. **Take it seriously!**

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- Best practice (especially for relatively risky debts): **write everything down**!
  - that way, you know what you need to fix before releasing

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    - **immediate benefit**: saves hard disk space (expensive in 1980)
    - **long-term cost**: if the program is still being used in 2000, need to fix it!
        - "I just never imagined anyone would be using these systems 10 years later, let alone 20."

[Philippe Kruchten, Robert Nord, Ipek Ozkaya: "Managing Technical Debt: Reducing Friction in Software Development"]

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    - the amount of technical debt you have is higher than if your bus factor was very high
- Other examples include having **high staff turnover** (which systematically lowers bus factor) or few senior engineers

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- system is successful initially; dev1 is promoted or moves on
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  - Systems evolve to meet new needs and add new features
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  - If the code's structure does not also evolve, it will "rot"

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Other similar choices include:

- middleware frameworks
- deployment pipeline
- major dependencies

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    - "Hack enables us to dynamically convert our code one file at a time" - Facebook Technical Lead, HipHop VM (HHVM)

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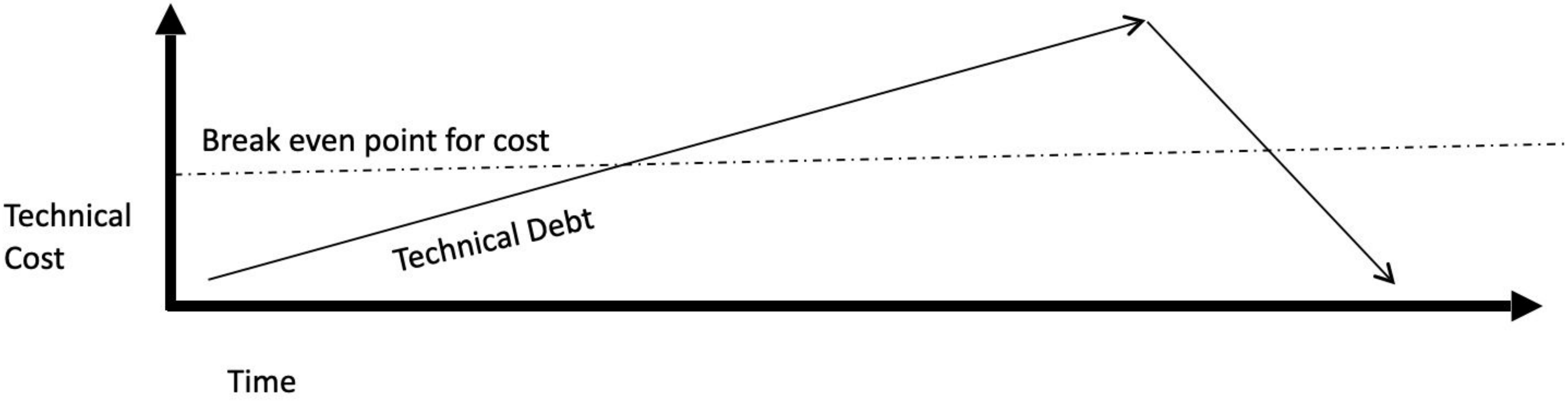
  - one option: **rewriting** the whole system (but think about next class' reading!)
  - more common: **refactoring** the code
- ***refactoring*** is the process of applying behaviour-preserving transformations (called ***refactorings***) to a program, with the goal of improving its non-functional properties (e.g., design, performance)

Paying down technical debt



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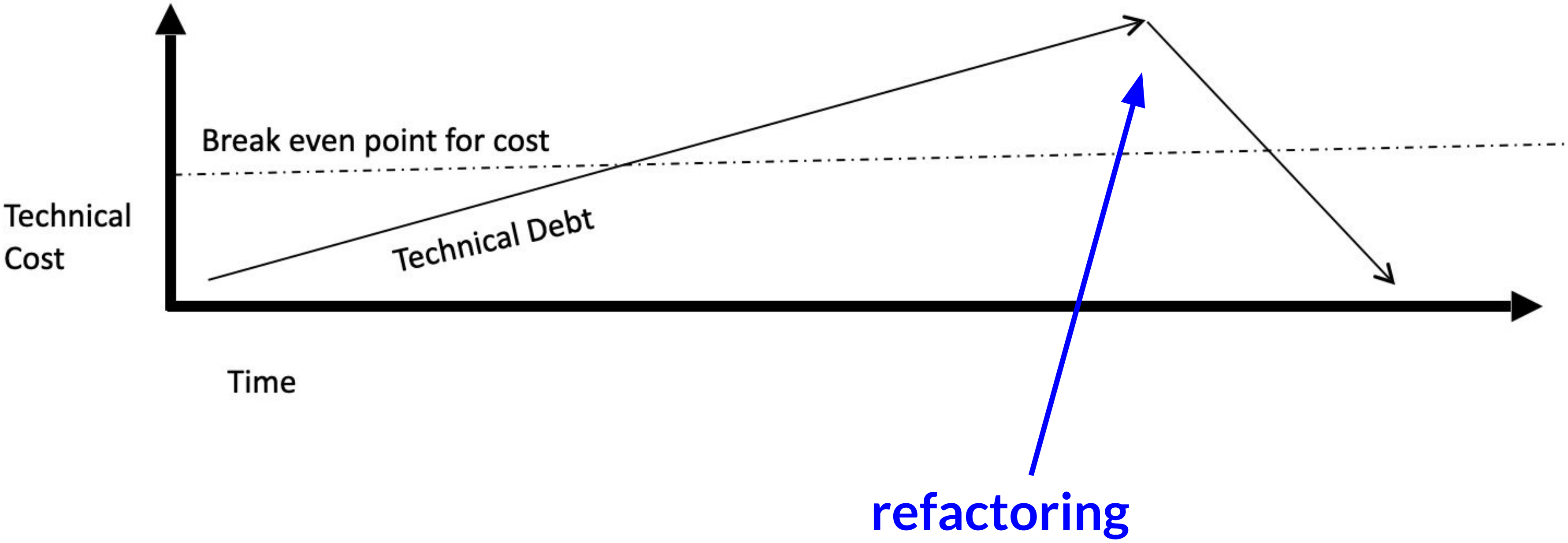

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- Have a plan: **don’t put off dealing with technical debt indefinitely**
  - When a crisis hits, it’s too late
  - Hasty fixes to unmaintainable code likely to multiply problems!
  - Eventually, mounting technical debt can bury a team

Tech debt, refactoring, and maintenance (1/2)

Today's agenda:

- Finish design pattern slides
- Reading Quiz
- Technical debt: the costs of bad design
- **How to pay off technical debt: refactoring**

Refactoring

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What refactoring is **not**:

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What refactoring is **not**:

- rewriting code
- adding features
- debugging code

Aside: rewriting code

- “refactoring code” != “rewriting code”

Refactoring: motivation

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- If the code does not do one or more of these, it ***is*** broken.
- Refactoring should improve the software's design:
  - more extensible, flexible, understandable, performant, …
  - every design improvement has costs (and risks)

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- many code smells -> good idea to refactor
- a good refactoring often fixes more than one code smell
  - sometimes many more than one

Refactoring: when to refactor

Examples of **common code smells**:

Refactoring: when to refactor

Examples of **common code smells**:

- Duplicated code
- Poor abstraction (change one place → must change others)
- Large loop, method, class, parameter list; deeply nested loop
- Module has too little cohesion
- Modules have too much coupling
- Module has poor encapsulation
- Dead code
- Design is unnecessarily general
- Design is too specific

Refactoring: “low-level” refactoring

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- “***low-level***” refactorings are small changes to the code that mitigate or remove one or more code smells. Examples:
    - Renaming (methods, variables)
    - Naming (extracting) “magic” constants
    - Extracting common functionality (including duplicate code) into a module/method/etc.
    - Changing method signatures
    - Splitting one method into two or more to improve cohesion and readability (by reducing its size)

also see https://refactoring.com/catalog/

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Refactoring: “low-level” refactoring

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  - ***IDE*** = “***integrated development environment***”
    - e.g., Eclipse, VSCode, IntelliJ, etc.
- they automate:
  - renaming of variables, methods, classes
  - extraction of methods and constants
  - extraction of repetitive code snippets
  - changing method signatures
  - warnings about inconsistent code
  - ...

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    - Clarifying a statement that has evolved over time or is unclear
- Compared to low-level refactoring, high-level is:
    - Not as well-supported by tools
    - But much **more important**!

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These are a good set of criteria for deciding to refactor code

- especially “needs new features”, because if you don’t refactor you’ll be **paying interest** on the tech debt!

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  - Add any **new features**.
  - As always, keep changes small, do code reviews, etc.